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(54) Title: ALUMINIUM-BASED ALLOY AND METHOD OF FABRICATION OF SEMIPRODUCTS THEREOF

(57) Abstract: This invention relates to the field of metallurgy, in particular to high strength weldable alloy with low density, of aluminium-copper-lithium system. Said invention can be used in air- and spacecraft engineering. The suggested alloy comprises copper, lithium, zirconium, scandium, silicon, iron, beryllium, and at least one element from the group including magnesium, zinc, manganese, germanium, cerium, yttrium, titanium. Also there is suggested the method for fabrication of semiproducts' which method comprising heating the as-cast billet prior to rolling, hot rolling, solid solution treatment and water quenching, stretching and three-stage artificial ageing.

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Aluminium - Based Alloy And Meth d f Fabricati n f Semiproducts There f

This invention relates to the field of metallurgy, in particular to high strength weldable alloys with low density, of aluminium-copper-lithium system, said invention can be used in air- and spacecraft engineering.

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Well - known is the aluminium-based alloy comprising (mass %):

			· ·	
	·	•	N.S. 70.5	
10	copper	2.6-3.3		
	lithiu m	1.8-2.3	23. g (<i>,</i> ,
	zirconium	0.09-0.14		,
	magnesium	≤0.1	7. (C. 1914)	را دن
	manganese	≤0.1	à.0-"@ ý	³ 4 1 :
15	chromium	≤0.05	no.	· · · · · · · · · · · · · · · · · · ·
	nickel	≤0.003	S. S. Berlin	ŧ.
	cerium	≤0.005		
	titanium	≤0.02-0.06	But the fitting the	
	silicon 30 % to fourth pa		made and more than the second	
20	iron	≤ 0.15	हार प्रीक्षी करणका हुनांगहा कर है।	r mores de la comité de
	beryllium The start I Hall and To Afold	0.008-0.1	essent i dia mandata natura Nota mangana sa	
	aluminium	balance	ewich et rapholaton et tarn es letelag bilthe billet all fi	್ ಕಟ್ಟಿಕೆ ಕಾಡಿಯ ಕಟ್ಟಿಕೆ - ಗಟ್ಟಿಕ್ಕಿಕ್ಕಿಕ

The disadvantage of this alloy is its low weldability, reduced resistance to impact loading and low stability of mechanical properties in case of prolonged low-temperature heating.

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and the substitutional supervision of the solid solution is a substitution of the solution of

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The aluminium—based alloy with the following composition has been chosen as a prototype:

(mass %) or a strong or but met in a six in a strong or but met in a six in the production of the prod

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	copper	1.4-6.0			
	TE HOLL			A STANCE OF THE	
5	zirconium	0.02-0.3	क्षानुकृतास्य गान्। ५५० १० । ३	THE FEW MERCHANT	٠,
	titanium	0.01-0.15		governor more s	
	boron	0.0002-0.07		•	
	cerium	0.005-0.15	righma volts balling o	and show the property field	
	iron	0.03-0.25		•	:
10	at least one element from the group	including:	たき 交流	· ·	
	neodymium	0.0002-0.1	\$ \$ 6.1	46 JA J	ι.
	scandium	0.01-0.35	9: 0.500	satt	
	vanadium	0:01-0.15	1918	the Court	
	manganese	0.05-0.6	ro.	india. Negro da	٠,
15	magnesium	0.6-2.0	Salar Contract	सामिताल	> 8
	aluminium	balance	The way	£25.79	a
			43K 102	1724FTL	•

The transfer of the second section of the second section is a second section of the second section of the second section is a second section of the second section of the second section secti

The disadvantage of this alloy is its reduced thermal stability, not high enough crack resistance, high anisotropy of properties, especially of elongation.

Well - known is the method of fabrication of semiproducts from alloys of Al-Cu-Li system, which method comprises heating of the billet at 470-537 °C, hot rolling (temperature of the metal at the end of the rolling process is not specified), hardening from 549 °C, stretching

(RU patent 1584414, C22C 21/12, 1988)

(E=2-8 %) and artificial ageing at 149 °C for 8-24 hours or at 162 °C for 36-72 hours, or at 190 °C for 18-36 hours.

1 1 1989) Add 1 1989 Patent 4.806.174, C22F 1/04, 1989) Add 11 1999 and the sub-to-train trails suffer

The shortcoming of this method is the low thermal stability of semiproducts' properties because of the residual supersaturation of the solid solution and its subsequent decomposition with precipitation of fine particles of hardening phases, and also the low elongation and crack resistance, all of which increases the danger of fracture in the course of service life.

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The well - known method of fabrication of products from the alloy of Al-Cu-Li system is chosen as a prototype, which method comprising: heating the as-cast billet prior to deformation at 430-480 °C, deformation at rolling finish temperature of not less than 375 °C, hardening from $525^{\circ \pm s}$ C, stretching (E=1,5-3,0%) and artificial ageing $150^{\circ \pm s}$ C for 20-30 hours.

(Technological Recommendation for fabrication of plates from 1440 and 1450 alloys, TR 456-2/31-88, VILS, Moscow, 1988).

10 The disadvantage of this method is the wide range of mechanical properties' values due to wide interval of deformation temperatures and low thermal stability because of the residual supersaturation of solid solution after ageing. 等位的 医牙顶 玩玩

The suggested aluminium-based alloy comprises (mass %):

The Cu/Li ratio is in the range 1.9-2.3.

15	व्यवस्थान विकास विकास	ලක්ක මේ විසුත් සුරු සියලුමුමුව ද අතර මෙස වෙන සියලුමුව නම් වෙන
15		LINGUE COLLEGE A CONTROL OF COMMENTERS AND A CONTROL OF THE PARTY OF T
	lithium	- 3.0-3.2 - 36 - 3.21 to 50% (29.3) - 1900 of 5 (m. 35.3) (1.25.3) (1.35.3) - 1.5-1.8
	t केडल १. ३० ज राज्या । zirconium	and Of 8 mi(1)* (3) - 11 s with
	mean or pail to its	1. L exidua bina 120d\C 1.35 fo 10 y 7 Lo 1 v 0 70 . 1
20	silicon	-0.02-0.15
	iron O Stasshorti erit "sanar beryllium	0.02-0.2 bi ਪੰਵਰੀਵਸ਼ਾਸ਼ਫ ਹੈਰ no touber ਸ਼ਿਤ੍ਰਿਲ-ਅਵਸ਼ੀ ਤਾਂ ਸਰਮਾਤਪਤਾ ਸਮਹਦ੍ਤਾਜ਼ ਜਾਂ ਕਿ ਸਮਾਤ ਸਤੋਂ 0.001-0.02
	at least one element from the	e group including
25	magnesium yn boibei (100 m) iza zinc manganese ——	0.1-0.6 (A.E.D. yillowsia now to be the implement of the loss of the control of the least of the control of th
	germanium	0.02-0.2
30	titanium (20, 8, 6, 0) mes, e. aluminium (20, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,	0.05-0.2 0.005-0.02 0.005-0.02 0.005-0.05 0.005-0.05 0.005-0.05 0.005-0.05 balance a why biologish a state of the
	The Cu/Li ratio is in the range	e in the transfer six property and the second six of the second si

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a la mai sili menduntara bi Also is suggested the method for fabrication of semiproducts, comprising heating of as-cast billet to 460-500 °C, deformation at temperature ≥ 400°C, water quenching from 525 °C,

stretching (E=1,5-3,0%), three-stage artificial ageing including: 5

| - 155-165.°C for 10-12 hours,

II - 180-190 °C for 2-5 hours,

III - 155-165 °C for 8-10 hours,

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with subsequent cooling in a furnace to 90-100 °C with cooling rate 2-5 °C/hours and air cooling to room temperature.

The suggested method differs from the prototype in that the billet prior to deformation process, is heated to 460-500 °C, the deformation temperature is not less than 400 °C, and the artificial ageing process is performed in three stages: first at 155-165 °C for 10-12 hours, then at 180-190 °C for 2-5 hours and lastly at 155-165 °C for 8-10 hours; then is performed cooling to 90-100°C with cooling rate of 2-5 °C/hour and subsequent air cooling to room าแล้โรกสระ temperature. 21/3 IND

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The task of the present invention is the weight reduction of aircraft structures, the increase in their reliability and service life. grafinalismi quorig aos morris intra trocau sexelita

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The technical result of the invention is the increase in plasticity, crack resistance, including the impact loading resistance, and also the increase in stability of mechanical properties in 一点的特别的特别 case of prolonged low-temperature heating. 1.445.6132

The suggested composition of the alloy and the method of fabrication of semiproducts from said alloy ensure the necessary and sufficient saturation of the solid solution, allowing to achieve the high hardening effect at the expense of mainly fine T₁-phase (Al₂CuLi) precipitates without residual supersaturation of the solid solution with Li, and that results in practically complete thermal stability of the alloy in case of prolonged low - temperature heating. things of the committee of the contraction of the c

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题 ART 11 14 15 11 15

Besides that, the volume fraction and the morphology of hardening precipitate particles on grain boundaries and inside grains are those, that they allow to achieve high strength and flowability as well as high plasticity, crack resistance and impact loading resistance.

Due to Al₃(Zr, Sc) phase particles' precipitation, the suggested alloy composition provides the formation of uniform fine-grained structure in the ingot and in a welded seam, absence of recrystallization (including the adjacent-seam zone) and hence, good resistance to weld cracks.

题(** 1271 2011 1964 1965 2013年,《基准》(1812年) ** 美拉

Thus, the suggested alloy composition and method for fabrication semiproducts thereof, allow to achieve a complex of high mechanical properties and damage tolerance characteristics including good impact behavior due to favourable morphology of hardening precipitates of T₁-phase upon minimum residual supersaturation of solid solution, which results in high thermal stability. The alloy has low density and high modulus of elasticity. The combination of such properties ensures the weight saving (15%) and 25% increase in reliability and service life of the articles.

The example below is given to show the embodiment of the invention.

Example

and the mean with single distributed frontes inverted alloy with inverted method

The flat ingot (90x220 mm cross selection) were cast from 4 alloy by semi-continuous method. The compositions of said alloy are given in Table 1.

The homogenized ingots were heated in an electric furnace prior to rolling. Then the sheets of 7 mm thickness were rolled. The rolling schedule is shown in Table 2. The sheets were water quenched from 525 °C, then stretched with 2,5-3 % permanent set. The ageing was performed as follows:

2%

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1 stage - 160 °C, 10-12 hours 2 stage - 180 °C, 3-4 hours ~ 3 stage - 160 °C, 8-10 hours.

The sheets made of the alloy-prototype were aged according to the suggested schedule and according to the method - prototype (150°C, 24 hours).

Some of the sheets (after ageing) were additionally heated at 115 °C, 254 hours, what equals to heating at 90 °C for 4000 hours when judging by the degree of structural changes or field, in the tables made care of teast. and changes in properties. A COMPANY OF A COMPANY OF A COMPANY

The results of tests for mechanical properties determination are shown in Tables 3-4. The data given in said Tables evidently show that the suggested alloy and method for fabrication of semiproducts, thereof as compared with the prototypes, are superior in hot rolled sheets properties, namely in elongation - by 10 %, in fracture toughness - by 15 %, in specific impact energy – by 10 % while their ultimate strength and flowability are nearly the same. Figure 1 to 10 Hz.

The highest superiority was observed in thermal stability of properties after prolonged low-20 temperature heatings. Strange

Thus, the properties of the sheets fabricated from the invented alloy by the invented method practically do not change. After heating nearly all the properties do not change by more than Enter the first of the control of the west the relative section of the control of 2-5 %.

On the contrary, the alloy-prototype showed: the ultimate strength and flowability increased by 6 %, elongation reduced by 30 %, fracture toughness reduced by 7 %, the rate of fatigue 1 (1991) crack growth increased by 10 %, impact resistance reduced by 5%. THE STREET AND AREA THOUGHT A SPECK THAT IN THE PARTY OF THE SHOOT OF THAT I STAND The comparison of the properties evidently show, that the suggested alloy and method for fabrication of semiproducts thereof can provide structure weight reduction (owing to high strength and crack resistance) by not less than 15 % and increase in reliability and service life of articles by not less than 20 %.

Table 1.

Compositions of the alloys, mass %

ted 1 3.4 1,5 0,08 0,09 0,04 0,02 0,07 0,3 0,15 0,0 0,01 0,02 0,00 0,28 0,31 0,0 0,01 0,10 0,00 0,00 0,00 0,00		:	(:		•	•
1 3,4 1,5 0,08 0,09 0,04 0,02 0,07 0,3 0,15	Alloy	Composition	3	3	17		izi				Mn	Zn	පී	F	X	4	All Cu/LI
2 3,48 1,76 0,11 0,069 0,05 0,02 0,06 0,28 0,31 0,07 3 3,1 1,63 0,07 0,1 0,0 0,0 0,00 0,0 0,0 0,3 0,3 0,3 4 3,0 1,75 0,11 0,09 0,08 - - 0,56 0,27	Invented			7	800	9	3	50.0								,	:
2 3,48 1,76 0,11 0,069 0,05 0,02 0,06 0,28 0,31 0,0 3 3,1 1,63 0,07 0,1 0,1 0,1 0,0 0,000 0,56 0,3 4 3,0 1,75 0,11 0,09 0,08 - - 0,56 0,27		- -		<u>.</u>	00,0	5	2	70,0			0,15	•		• •	- 0,001 Bal.	Bal.	2,26
3 3,1 1,63 0,07 0,1 0,09 0,08 0,00 0,08 0,31 0,0 4 3,0 1,75 0,11 0,09 0,08 - 0,56 0,27			07 6	126	770	0,00	100	000	ı								
3 3,1 1,63 0,07 0,1 0,1 0,2 0,0001 0,56 0,3 4 3,0 1,75 0,11 0,09 0,08 0,56 0,27		7	2,40	<u> </u>		690'0	Ω Ω	70,0		0,28	0,31	0,02	•	0,02	- 0,02 0,001 Bal.	Bal	1,98
4 3,0 1,75 0,11 0,09 0,08 - 0,56 0,27		C	_	5	100	1	ļ					l				Ç	
4 3,0 1,75 0,11 0,09 0,08 0,56 0,27	!	Λ'		<u>5</u>)))	o O	5		0,0001	0,56	0,3		- 0,1 0,02	0,02		- Bal	1.90
4 5,0 1,75 0,11 0,09 0,08 - 0,56 0,27	Dring Art / Drotot in c)	¥	c	1	;	000										::'	
	riidi Air (ri ororype)		0,0	<u>Ş</u>)))	20.0	•	ì	0,56	0,27		•	- 0'05	•	- Bal.	171

Technological schedule of fabrication of the sheets.

Alloy	Composition	Composition Temperature of	of Temperature of Permanent set	Permanent set		Ageing	
		billet heating prior to	neating prior to metal at rolling at stretching of in the	atetratching 00		00	
		0	9	מר שו בורכונווו ללי ש		2 Stage	3 stage
		rolling. °C	finish, °C	71 202		0°.) i ' ' ' ' ' ' ' ' ' '
Invented		0		20	00 000		-
					180 °C, 10h 180 °C, 3h 160 °C, 10h	780 °C, 3h-	160°C, 10h
	2	460	410	2,5	160 °C, 12h - 180 °C, 4h 160 °C 10h	180 °C, 4h	160 °C 10h
	2	460	710	LC			120
		A Second Property of the Control of	2	67	160 °C, 10h 180 °C, 3h 160 °C, 8h	180°C, 3h	160 °C, 8h
Prior Art 4	4	480	400	2,8	160 °C, 10h	-	180°C 3h 160°C 10h
(Prototype)	Ψ,	VõV					3 3
יי ימימיל אבי	•	100	280	7,8		150 °C, 24h	-
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Note: 1) sheets of alloy 1-3 prior to stretching, were hardened from 525 °C, of alloy 4 – from 530 °C

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2) 4' - ageing according to prototype method.

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Table 3.

Mechanical properties of hot-rolled sheets in as-aged condition (longitudinal direction)

Alloy	Composition UTS, MPa	UTS, MPa	YTS, MPa	Elongation, %	Critical*	Fatione crack	Specific impact
	٠ ١						שליים ביישר
			ڊ رد، د		coefficient of	growth rate	energy under
•	. a				stress intensity	'Np/lp	loading E,
					Ko, MPavm	mm/k cycl.	J/mm
				;	ΔK=32	ΔK=32	
	: :	<u>-2</u>			MPavm	MPa/m	; ;
			9	ps.			
Inventive		569		<u>ر</u> ې د د د د د د د د د د د د د د د د د د د	65,8	2,35	18.2
	2.	657	542	9.1	64,3	2,4	
	3.	560	530,	10,8	66,4	2,2	18.4
Prototype	4	570	540	8,9	58,6	3,68	16.1
	4,	250	523 C. C. C. III		. 69.2	2,6	169
						•	\ <u>`</u>

*width of samples (w) – 160 mm

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Table 4

258	S Mechani	Mechanical properties of hot-rolled sheets after prolonged low-temperature heating (115 C, 254 hours)	rolled sheets aft	er prolonged lov	<i>N</i> -temperature h	eating (115 C, 2	54 hours)
	nga sar Tida					e for e smallseld g bell red given ye	
Alloy	Composition	Composition UTS, MPa	YTS, MPa	Elongation, %	Critical*	Fatigue crack	Specific impact
1) F			• ·		coefficient of	growth rate	energy under
	N	_			stress intensity	:	loading E,
	1.7				K _{co} , MPa√m	mm/k cycl	J/mm
71 <u>k</u>	41 f			-	ΔK=32	2903	•
	7 - 5 1 1				MPa√m	MPavin San	
	13 (> () 3			, te ²		76620 7 - 690 7 - 9 - 9 800 - 90	បច្ច
Inventive	734; 57	, y &	534 C. O	5.6	64,5).	18,0
	ੀ ਹਾਂ ਮ ਹ	7-0 3-0 35 38.	545	8,4 %	65.2	2,4	17,6
Çar.	estica Mariota	265	532 € €	ું ે ⊆9'01	67,2	2,1	18,5
Prototype	4	299	267	6,4	58,1	3,71	15,4
,	4'	586	547	8,1	64,2	2,9	16,2

Claims

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copper

1. Aluminium-based alloy comprising copper, lithium, zirconium, scandium, iron and at least one element from the group including, magnesium, manganese, which alloy is characterized in that it additionally comprises silicon and beryllium and at least one element from the group including magnesium, manganese, zinc, germanium, yttrium, cerium, titanium, having the composition within the following ranges (mass %):

3.0-3.5

	lithium	: : : : : : : : : : : : : : : : : : : :	1:5-1:8 🗥
15	zirconium		0.05-0.12
	scandium		0.06-0.12
	silicon		0.02-0.15
	iron	ì	0.02-0.2
	beryllium		0.0001-0.02
20	at least one element f	rom the group	including
	magnesium	1	0.1-0.6
	zinc		0.02-1.0
	manganese	<u>&</u>	0.05-0.5
	germanium		0.02-0.2
25	cerium		0.05-0.2
	yttrium		0.005-0.02
	titanium		0.005-0.05
	aluminium.		balance,
•	the Cu/Li ratio is in th	ne range 1.9-2	

2. Method for fabrication of semiproducts from the alloy of claim 1, which method comprising heating of as-cast billet, hot deformation, solid solution treatment and water quenching, stretching, artificial ageing and final cooling, which method is characterized in that the billet

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prior to deformation process, is heated to 460-500 °C, the deformation temperature is not less than 400 °C, and the artificial ageing its performed in three stages: first at 155-165 °C for 10-12 hours, then at 180-190 °C for 2-5 hours and lastly at 155-165 °C for 8-10 hours; then is performed cooling to 90-100 °C with cooling rate of 2-5 °C/hour and subsequent air cooling to room temperature.

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